SUMAS2 GENERATION FACILITY – AIR QUALITY ISSUE SUMMARY

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Re: Sumas 2 Air Quality Summary

As per the discussion at your meeting of July 18th with Minister Sawicki, please find attached an early draft of a summary of air quality issues associated with the Sumas Energy 2 (SE2) proposal. The draft is authored by an inter-agency technical committee comprised of members of this Ministry, the Greater Vancouver Regional District and Environment Canada.

The summary is largely based on the current knowledge of air quality in the Lower Fraser Valley, and several different model predictions of the air quality impacts associated with the proposed facility emissions. Regulatory agencies around the world use such atmospheric dispersion models to assess source emissions and their impact on air quality. While any model produces estimates with uncertainties, it is important to note that the air quality agencies had input to the technical specifications and application of the models used by the company consultant and by Environment Canada.

The summary is a draft in progress, and subject to change before it is finalized. The air quality information related to this proposed project is considerable and technically challenging, and the inter-agency committee is continuing to review and comment on this working draft. In addition, the company has provided a list of potential mitigative measures to the Ministry, including willingness to reduce the emissions of oxides of nitrogen (NOx) to approximately two-thirds of the originally specified emissions. The draft summary reflects the air quality implications associated with the originally proposed emissions and, as such, does not incorporate the improvements in air quality impacts that will occur with these additional reductions in NOx. Finally, an analysis of potential health impacts associated with predicted air quality changes is currently under review by experts at the Ministry of Health.

.../2

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The draft air quality summary was shared with the City of Abbotsford as part of the Ministry's commitment to provide technical support for their intervention at the regulatory hearings. It is also being provided to EFSEC, the proponent, and Mary Barrett (appointed counsel for the hearings) as part of the ongoing information exchange that has been occurring throughout the process.

I trust that this draft summary will be helpful to you. We will send an updated summary to you once we have received the Ministry of Health comments and had further discussions with the company regarding mitigation measures and offsets proposals, and assessed their implications. We will also provide a separate reply regarding a number of the issues raised in your letter to the minister.

Sincerely,

for.

Lynn Bailey
Director, Air Resources Branch

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SUMAS2 GENERATION FACILITY – AIR QUALITY ISSUE SUMMARY

1. INTRODUCTION

Sumas Energy 2, Inc. proposes to build a 660 MW natural gas-fired electrical power generation facility called the Sumas 2 Generation Facility (S2GF). It is to be located south of Abbotsford in the State of Washington, less than 1 km from the Canada/U.S. border (see Figure 1). Nearby is the existing 125 MW Sumas generation facility.

Although located in the U.S., if built S2GF will emit pollutants into the Lower Fraser Valley (LFV) airshed, an area shared by B.C. and Washington. This airshed is under active air quality management by B.C. agencies as it is already prone to periods of poor air quality (elevated levels of ground-level ozone, inhalable particulate and visibility impairment).

The Washington State Energy Facility Site Evaluation Council (EFSEC) co-ordinates all of the evaluation and licensing steps for siting major energy facilities in Washington. It has delegated authority from the U.S. Environmental Protection Agency to issue permits under the Federal Clean Air and Clean Water Act. The Ministry of the Environment, Lands and Parks and its LFV partner agencies involved in airshed management have been interacting with EFSEC and the proponent regarding the air pollution issues associated with this proposal.

An inter-agency committee was established to review the technical aspects of the air quality issues associated with S2GF and to insure that the studies conducted by the proponent's air quality consultant (MFG) were credible and relevant to B.C. decision makers. The committee consists of members from the Ministry of the Environment, Lands and Parks, Greater Vancouver Regional District and Environment Canada. This air quality issues summary is based on a review of (i) analysis conducted by MFG, (ii) air quality conditions in the region, (iii) current ambient air quality objectives/thresholds, and (iv) independent analyses conducted by committee (which is identified in the text).

Figure 1 Proposed Facility Site and Surrounding Area

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2. PROJECT EMISSIONS

S2GF can have a variety of operational modes, each with a corresponding emission rate. There are two conditions where maximum emissions occur: a) gas firing operation at maximum electrical production (base load with duct firing) and b) oil firing. Oil firing occurs when the supply of gas is cut off (peak gas demand periods during the winter). This is anticipated a maximum of 15 days/year during the winter. Since oil does not burn as cleanly as natural gas, the pollutant emissions are the greatest during these periods.

S2GF pollutant emissions include oxides of nitrogen (NOx), carbon monoxide (CO), sulphur oxides (SOx), volatile organic compounds (VOCs), inhalable particulate (PM10) and carbon dioxide (CO2). There are also residual emissions of air toxics. S2GF emissions of common contaminants and their contribution relative to all LFV sources are summarized Table 1.

Table 1. S2GF Emissions Relative to LFV Emissions

Pollutant	S2GF Annual Emission [1] (Tonnes/year)	S2GF Peak Load Emissions Expressed as a Percentage of all (B.C. and Washington) 1995 LFV Sources
NOx as NO_2	214	0.31%
CO	92	0.03%
SO_2	41	0.09%
VOC	142	0.15%
PM10	202	1.39% (excludes road dust) [2]

[1] Emissions conservatively based on a full 15 days of oil firing (maximum anticipated) and 350 days with duct firing (max electricity production).

[2] Although inventory studies show that road dust is a significant contributor to the PM10 emissions in the LFV, it is excluded from the calculation due to concerns that current road dust emission estimates are unrealistically high. With respect to *all* LFV PM10 emissions, the S2GF contribution of 1.39% would certainly be a conservative estimate

Although S2GF will emit many tonnes of pollutants into the LFV airshed its relative contribution to all emissions in the LFV is small – in the order of 1% or less. This illustrates the potential significance of other sources of pollution that contribute to periods of poor air quality. However, as the following sections will show, the ambient air quality impacts due to S2GF emissions can be much greater than implied by a simple examination of the relative emissions contribution.

Under both gas and oil firing, there are also residual emissions of air toxics. The short-term emission rates are listed in Table 2a and b (oil firing).

Table 2a. Toxic Air Pollutant Emission Rates for Gas Firing – Base Load with Duct Firing

Compound	Short-term Emission Rates per Turbine (kg/hr)
Acrolein	0.009
Ammonia	14.5
Ethylbenzene	0.027
Naphthalene	0.160
Sulphuric Acid Mist	0.064
Toluene	0.148
Xylenes (m-,o-,p-isomers)	0.031
Mercury	0.0005
Acetaldehyde	0.091
Benzene	0.160
Formaldehyde	0.0114
PAHs	0.0009
Arsenic	0.00005

Table 2 b Toxic Air Pollutant Emission Rates – Oil Firing

Compound	Short-term Emission Rates per turbine (kg/hr)
Ammonia	11.3
Chromium	0.0055
Lead	0.0087
Manganese	0.349
Mercury	0.0005
Naphthalene	0.025
Selenium	0.0186
Sulphuric Acid Mist	8.5
Acetaldehyde	0.025
Arsenic	0.0064
Benzene	0.044
Beryllium	0.0003
Cadmium	0.0026
Chromium VI	0.00009
Dioxins	2.7E-07
Formaldehyde	0.186
Furans	7.5 E-07
Nickel	0.070

3. EMISSION CONTROL TECHNOLOGY

S2GF will burn natural gas to produce electricity. The burning of natural gas produces nitrogen oxides (NOx) as well as a variety of other compounds. NOx is a key ingredient in the formation of ground-level ozone and inhalable particulate. It contributes to both visibility degradation and acid deposition. Thus, out of all the all the products of combustion, for these kinds of facilities NOx is traditionally the focus of emission control methods.

3.1. S2GF Emission Control Technology – BACT

As part of the permit approval process, the proponent conducted a Best Available Control Technology (BACT) analysis. This involves a review of other facilities of this type, the emission control technology and the State and local emission limits. On the basis of the BACT review, S2GF proposes to use state-of-the-art, gas fired turbines in combination with a post-combustion NOx control device called Selective Catalytic Reduction (SCR). This technology employs a catalyst (similar to the catalytic converter in a car) as well as the injection of ammonia into the exhaust gas to strip out NOx. One of the disadvantages with this control technology is the emission of residual ammonia into the atmosphere (called ammonia slip), which can have direct effects on the environment and can contribute to the formation of inhalable particulate.

In an effort to reduce emissions of carbon monoxide and to a lesser extent, volatile organic compounds, an oxidation catalyst is proposed.

3.2. Comparison to Other Gas-Fired Power Generation Facilities in B.C.

The combination of modern turbine and emission control technology means that S2GF is more efficient and cleaner than other similar facilities in B.C. Burrard Thermal is an older gas-fired power generation plant in the LFV that has recently been fitted with SCR. Natural gas is burned to produce steam which turns the turbines. There is no need for oil as a back up fuel, as Burrard Thermal is part of the large BC Hydro system and has traditionally been used to support the integrated power network. If natural gas is unavailable, other hydro-based power resources in the B.C. can be used to supply power.

ICP (Campbell River) is a recently approved gas-fired, electrical generation facility. It is similar to S2GF in that the hot exhaust gas from gas combustion turns the turbines. After leaving the turbine the exhaust gas is used to generate steam which turns yet another turbine to produce additional electricity. This is called cogeneration. More electricty can be generated from S2GF and ICP than Burrard Thermal for the same amount of supply natural gas. However unlike S2GF, the ICP facility does not have SCR or an oxidation catalyst system.

Table 3 provides a comparison between the potential maximum emissions for each of these facilities. The figures of S2GF were based on information supplied by the proponent. The Burrard data was produced by the technical committee.

Table 3. Potential Maximum Emissions (Tonnes/Year)

Facility	Generation Capacity (MW)	Maximum Emission (Tonnes/Year)				
		CO	VOC	SOx	PM	NOx
ICP (Campbell R) [1]	245	912	169	214	70	612
Burrard Thermal [2]	960	215	155	70	212	490
S2GF [3]	660	92	142	41	202	214

[1] ICP permit application information. No oil firing conditions included although there is a potential of 10 oil firing days.

[2] Burrard Thermal can potentially produce a maximum of 7000 GW h/year of electricity. However due to its supportive role in the electricity grid, its production has ranged anywhere from 6 to 60% of this maximum. The PM, SOx and NOx emissions are theoretical (potential) maximums as they are based on the potential power generation maximum (7000 GW h) and factors based on operating/emissions data.

[3] S2GF annual emissions assume a full 15 days/year oil firing (maximum anticipated).

Comparisons between these facilities are complicated by the fact that they are different sizes (i.e. have different power generation capacities). A more meaningful comparison is on the basis of emissions per unit energy produced. This is shown in Table 4.

Table 4. Emissions Per Unit of Electricity Produced (kg/GWh)

Gas Fired Power Generation Facility	Max Annual Electricity Production (GW hr)	Emissions Per Unit of Electricity Produced (kg/GWh)				
		CO	VOC	SO2	PM	NOx (as NO2)
ICP (Campbell R)	2000	457	85	107	35	306
Burrard	7000	31	22	10	30	70
Sumas2	5800	16	25	7	35 [1]	37

[1] Based on turbine manufacturer emission specifications which are regarded as conservative. A full 15 day/year oil firing scenario is factored into these estimates.

The two pollutants of interest are NOx and PM. Of the two, NOx is a critical pollutant to control due to its direct impacts, and its involvement in the formation of ground level ozone, acid deposition, inhalable particulate (PM10) and visibility degradation. Although Burrard and S2GF both have SCR to control NOx emissions, the S2GF emissions/GWh are lower as S2GF has new turbine technology and is more efficient than Burrard.

With respect to PM10, it should be noted that Tables 3 and 4 indicate only *primary* (or directly emitted) PM. There is also a *secondary* PM component that should be included when considering the *total* PM loading due to a facility. Secondary PM is created when gaseous NOx and SO2 transform into PM10 through complex atmospheric processes. This complexity makes it difficult to estimate the amount of secondary PM formation.

Although the Burrard primary PM10 emission (kg/GWh) is less than S2GF, the NOx and SO2 are higher resulting in the formation of more secondary PM10 than what S2GF would create (assuming identical atmospheric conditions at both facilities). Thus if the *total* facility PM contribution were considered, the difference between the S2GF and Burrard PM emissions (kg/Gwh) may be small or even negative (S2GF total PM contribution may be less than Burrard).

There are significant ammonia emissions from S2GF and Burrard due to the SCR control process. For S2GF a conservative estimate (350 days duct firing, 15 days oil firing) based on Tables 2a and b indicates an annual emission of 250 T/y. Burrard maximum permitted emissions are estimated to be 171 T/y, but actual stack sampling data indicate that under maximum power generation, ammonia emissions will be $1/7^{th}$ the permitted amounts. ICP does not have SCR, thus has no associated ammonia emissions. Ammonia can have direct impacts on the environment, as well it can react with NOx and SO2 to create PM. The ammonia impacts are discussed in the following Air Quality Issues section.

3.2.1. Summary

- On the basis of the BACT review, the proponent proposes to use modern gas fired turbines in combination with SCR control technology. In addition, an oxidation catalyst is proposed to achieve reductions of CO and to a lesser extent, VOC's. This technology is generally cleaner than used for other similar facilities in BC.

- NOx emissions per unit of electricity produced from S2GF are about ten times smaller than ICP and about two times smaller than Burrard Thermal. NOx is a critical pollutant to control due to its direct impacts, its involvement in the formation of ground-level ozone, acid deposition, inhalable particulate and visibility degradation.

- The PM contribution is best given by both the primary and secondary PM attributed to the facility. Although primary Burrard PM emissions/GWh are lower than S2GF, due to its greater NOx and SO2 emissions it has a greater potential to create secondary PM. Thus on the basis of *total* PM contribution it is not clear which facility has lower emissions on a kg/GWh basis.

- There are significant ammonia emissions associated with SCR.

4. AIR QUALITY ISSUES

What kind of impact will S2GF have on local air quality (within 10 km of the plant), and on regional air quality in the LFV?

The answer to this question lies partly in the predictions produced by air quality computer models. These models solve mathematical equations, which describe the behaviour of S2GF emissions in the atmosphere. The U.S. regulatory agencies and the Ministry of Environment, Lands and Parks approved the air quality models (ISC, CALPUFF) used by the consultant (MFG) and provided guidance as to their proper application. Environment Canada also applied a sophisticated regional model (UAM) to examine ground-level ozone changes that would occur as a result of S2GF emissions.

One of the key model inputs is the emission rate. S2GF can have a variety of operational modes each with a corresponding emission rate. Since predictions of the maximum potential impacts are of interest, maximum emissions rates are input to the models. It is assumed that these maximum rates apply for every hour of the simulation period (at least one-year), even though these rates may actually only occur for a few days. This provides some assurance that the model predicted concentrations would be higher than they would be in reality (i.e. they are conservative).

For S2GF, there are two conditions where maximum emissions occur: a) operation at maximum generation capacity (duct firing) and b) oil firing. It is these emission scenarios that were the focus of the modelling studies.

4.1. Criteria Pollutants (SO2, NO2,CO) and Air Toxics

The following tables provide the maximum model predicted concentrations for a variety of pollutants and air toxics. The predictions were based on the results of the ISC model, which was run for a 5-year period using Abbotsford airport meteorological data. As well, air quality monitoring information in the Abbotsford area provided estimates of the existing levels experienced in the region. The maximum measured levels are also listed along with the most stringent Canadian Air Quality Objective and in the case of air toxics, the relevant Washington threshold levels and applicable B.C Objectives.

The Tables indicate that for NO2, SO2, CO and residual toxics, predicted impacts due to S2GF emissions are below the most stringent Canadian, B.C. and Washington State objectives/levels.

Table 5 Predicted maximum ambient concentrations of SO2, NO2 and CO in British Columbia due to emissions from S2GF, and comparison with Canadian Objectives – background levels included.

Air Contaminant	Averaging Period	Predicted Maximum Ambient Concentration [1] ($\mu g/m^3$)	Maximum Background Level [2] ($\mu g/m^3$)	Total Maximum Ambient Concentration ($\mu g/m^3$)	Most Stringent Canadian Objective ($\mu g/m^3$)	Total Maximum Concentration as a Percentage of Objective (%)
Sulphur Dioxide (SO_2)	1-hour	57	37	94	450	21
	3-hour	35	28	73	375	19
	24-hour	11	9	20	150	13
	1-year	0.06	2	2	25	8
Nitrogen Dioxide (NO_2)	1-hour	51	117	168	400	42
	24-hour	9	62	71	200	36
	1-year	0.44	33	33	60	55
Carbon Monoxide (CO)	1-hour	31	7,760	7,791	14,300	55
	8-hour	12	3,419	3,419	5,500	62

[1] There are higher maximum concentrations occurring in Washington State. All the short-term maxima occur under oil-firing.
[2] The maximum background level is the maximum concentration measured at the Abbotsford ambient monitoring station between 1996 - 1998

Note: With the exception of the maximum 1-hour averaging period, the maximum concentrations are located at the same receptor on Sumas Mountain (elevation 180 m, 6 km NNE of S2GF). The maximum 1-hour concentration occurs on a small hill on the B.C. side of the border, 800 m N of S2GF. These 1-hour maximums were predicted to occur once in five years.

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Table 6. Predicted maximum 24-hour average ambient concentrations of toxic air contaminants in British Columbia due to emissions from S2GF, and comparison with Washington State Acceptable Source Impact Level (ASIL) values - background levels not included when using ASIL values.

Air Toxic	Predicted Maximum[1] 24-hour Average Concentration ($\mu g/m^3$)	Washington 24-hour Average ASIL ($\mu g/m^3$)	Maximum Concentration as a % ASIL	British Columbia Objectives ($\mu g/m^3$)[2]
Acrolein	0.0033	0.02	16.5	
Ammonia	5.2	100	5.2	
Chromium	0.0014 *	1.7	<0.1	0.05-0.1
Ethylbenzene	0.0099	1000	<0.1	
Lead	0.0022 *	0.5	0.4	1.0-2.5
Manganese	0.0891 *	0.4	22.3	
Mercury	0.0002	0.17	0.12	0.1-1.0
Naphtalene	0.0578	170	<0.1	
Selenium	0.0048 *	0.67	0.7	0.1-1.0
Sulfuric Acid Mist	2.17 *	3.3	65.8	
Toluene	0.0536	400	<0.1	
Xylenes	0.011	1500	<0.1	

* Occurs under oil-firing.

[1] There are higher maximum concentrations occurring in Washington State.

[2] From Pollution Control Objectives for the Mining, Smelting and Related Industries of British Columbia 1979. Averaging times are up to the discretion of regional managers. However, for the purpose of this evaluation, they are taken to be 24-hour averages.

Table 7. Maximum Annual Toxic Air Pollutant Concentrations

Pollutant	Maximum Annual Concentration in B.C. (µg/m3) [1]	Annual Ecology ASIL (µg/m3)	Maximum Annual Concentration as a % of ASIL
Acetaldehyde	3.03 E-03	4.50 E-01	0.67
Arsenic	8.04 E-06	2.03 E-04	4.0
Benzene	5.77 E-03	1.20 E-01	4.8
Beryllium	2.52 E-07	4.20 E-04	0.06
Cadmium	2.47 E-06	5.60 E-04	0.44
Chromium VI	6.58 E-08	8.30 E-05	0.08
Dioxins	2.58 E-10	3.00 E-08	0.86
Formaldehyde	5.85 E-04	7.70 E-02	0.76
Furans	7.13 E-10	3.00 E-08	2.4
Nickel	6.58 E-05	2.10 E-03	3.13
Polynuclear aromatic hydrocarbons	3.33 E-05	4.80 E-04	6.9

[1] Annual concentrations based on a full 15 days of oil-firing and 350 days gas-fired with supplemental duct burners.

4.1.1. Summary

- The impact due to the S2GF emissions of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and CO to the existing air quality will not result in any exceedances of the most stringent B.C. or national air quality objectives for these pollutants.

- There will be no exceedances of the short and long-term Washington State or applicable B.C. objectives for the air toxics impacts due S2GF emissions.

- The highest short-term maximum concentrations for NO2, SO2 and CO and many of air toxics occur under oil firing.

4.2. Acid Deposition

The nitrogen and sulphur oxides (and the resulting nitrate and sulphates) emitted by S2GF will deposit on surfaces, either through direct surface contact (dry deposition) or through precipitation (wet deposition). The fraction of wet and dry to the total deposition depends on factors such as precipitation amounts and surface characteristics. There are natural sources of these compounds, which means that depositions occur even in remote areas. Depositions of these

compounds are linked to acidification of the water and soil and are thus referred to as acidic deposition.

Recent measurements (Feller, 2000) of annual deposition at the University of British Columbia research forest (just N of Haney) range from 2.5 to 7.0 kilograms per hectare for nitrogen (average is 4.4) and 2.3 to 7.9 kilograms per hectare for sulphur (average is 5.2 kg/ha/y). The measurement methodology provides the wet deposition component and some portion of the dry (although the exact fraction is not known). For this discussion it is assumed that these numbers represent an estimate of total deposition.

Are these current levels acceptable? There are no official Canadian or B.C. deposition threshold values (critical loads) to help answer this question. Studies in Eastern Canada showed that critical loads for lakes varied from 2.67 to 6.67 kg/ha/y sulphur (wet deposition only) FPRMCC (1990). Alberta has adopted critical loading criteria which uses the Potential Acid Input method to express acid deposition in keq H^+/ha/y (TLS, 1999). Areas of high, moderate and low sensitivity to acid deposition are identified as well as the corresponding critical loads for these areas.

The critical loading levels applicable for Eastern Canada or Alberta may have little relevance for coastal B.C. the values depend on the characteristics of the receiving environment. Perhaps the most relevant to the LFV are those used by the U.S. Forest Service for the Pacific Northwest where thresholds of less than 5 kg/ha/y nitrogen are considered protective of terrestrial ecosystems and 3 kg/ha/y sulphur for sensitive lakes.

Model predictions indicate that the maximum annual deposition impact due to S2GF emissions will be 0.05 kg/ha/y nitrogen and 0.07 kg/ha/y sulphur. These maxima occur over a small area on top of Sumas Mountain.

This suggests that the deposition increase due to S2GF emissions relative to current LFV average deposition are predicted to be less than 1.3% for both nitrogen and sulphur areas away from Sumas Mountain. This percentage drops to less than 0.4% at a distance of a few km from this maximum impact area.

4.2.1. Summary

- The technical committee notes that the predicted incremental contribution due to S2GF emissions relative to current deposition levels is small, and is limited to an area on Sumas Mountain.

- The technical committee also notes that historical LFV deposition measurements indicate some years have experienced depositions higher than the U.S. Forestry thresholds for terrestrial ecosystems and sensitive lakes in the Pacific Northwest.

4.3. Ground-Level Ozone

The oxides of nitrogen and other compounds called volatile organics that are emitted from S2GF can undergo complex chemical reactions and form ground-level ozone under conditions of elevated temperature and sunlight. Ozone is also produced from natural processes in the atmosphere; and thus ground-level ozone occurs in remote areas of the world.

During the summer, the LFV experiences occasional exccedances of the current ambient air quality objective for ozone. The LFV was designated in the Canadian Council of Ministers of Environment NOx/VOC Management Plan as one of three regions in Canada with ozone problems which warrant remedial actions (eg. such as Air Care and the GVRD Air Quality Management Plan). There are concerns that the emissions from S2GF will aggravate this situation.

4.3.1. The Current Ozone Objective

The ozone objective which has historically been used for ozone assessments is the Canadian national ambient air quality maximum acceptable objective (1 hour average) level of 82 parts per billion. Periods when this threshold is exceeded at one or more monitoring stations for three or more consecutive hours are called ozone episodes. In the Lower Fraser valley there are an average of one to three episodes per year – a significant decrease from the 1980's.

In order to determine the increase in ozone concentrations as a result of S2GF emissions, Environment Canada applied a sophisticated model for a select set of meteorological conditions that are considered to be associated with a typical summer episode period. The results show that increases in ozone might be as high as 5 parts per billion but more likely will be less than 2 parts per billion under episode conditions. Beyond 5 kilometres from the facility, the increases drop by 75 percent. That is the ozone levels drop to ..... The duration of the ozone episode does not increase.

4.3.2. A New Canada Wide Standard for Ozone.

A new air quality standard for ground-level ozone was approved by the Canadian Council of Ministers of the Environment in early June through the Canada Wide Standards (CWS) process. The original air quality objective (82 ppb) has not been rescinded; discussions on its role and use are currently underway. Given this, an assessment was conducted by the technical committee to determine the implications of the S2GF emissions relative to this new standard.

The new CWS for ozone is 65 ppb (daily 8-hour maxima, based on the 4th highest annual measurement, averaged over three consecutive years). However, based on analysis of data collected between 1994-1998, it appears

that most areas of the LFV which previously exceeded the air quality objective did not exceed the CWS. The lone exception is Hope, where exceedances of the CWS and original air quality objective were calculated.

Since there are no present ozone CWS exceedances in Abbotsford, and the predicted ozone increase due to S2GF is small, and limited in time and space, it is unlikely that the S2GF emissions will create exceedances of the ozone CWS.

4.3.3. Summary

- On average, one to three ozone episodes per year occur in the LFV.
- Environment Canada modelling indicates that S2GF emissions will result in a small increase in the intensity but no increase in duration of common ozone episodes. The increase in ozone is limited to a few kilometers around S2GF and thus no impacts are expected in Abbotsford.
- Analysis by the technical committee indicates that there have been no exceedances of the proposed ozone CWS in the Abbotsford area for the analysis period (1994-1998). Given the limited magnitude and area of the predicted ground level ozone impact due to S2GF emissions, it is unlikely that S2GF will result in an exceedance of the ozone CWS.

4.4. Particulate Matter (PM)

Particulate matter (PM) refers to microscopic solid and liquid particles, other than pure water, that are found in the atmosphere. Those particles less than 10 micrometres in diameter are referred to as PM10 (inhalable particulate – small enough to be inhaled into the lungs), and those less than 2.5 micrometres are referred to as PM2.5. PM impacts due to S2GF emissions are a result of direct PM emissions, and also PM formed in the atmosphere from emitted gases (secondary PM).

Monitoring data indicate that PM10 concentrations in the eastern end of the LFV periodically contribute to periods of poor air quality (GVRD/FVRD, 1999). Given the PM10 emissions from S2GF, and the gases emitted that could transform into PM10, there is a potential for the S2GF emissions to aggravate this situation.

The assessment of the PM10 impacts involved two different air quality models (ISC and CALPUFF). The model output was used with existing Abbotsford PM data to examine two aspects of the PM impacts: relative to the current B.C. air quality objective and relative to the new Canada Wide Standard (CWS) for PM.

4.4.1. The PM10 Prediction Methodology – Two Air Quality Models

The ISC model was applied to simulate S2GF PM10 impacts over 5 years. It does not account for the formation of secondary PM and does not handle light wind conditions. This could lead to an underprediction of PM. However it has other assumptions (such as its treatment terrain interaction with the plume) that can result in an overprediction bias. ISC was used as its relative simplicity allowed it to provide long-term statistics needed for the CWS assessment.

The other model, CALPUFF, is more sophisticated in that it accounts for the secondary PM and light wind conditions. In theory, it should provide a better prediction of PM10 than ISC. However, due to its complexity it demands considerable computer resources. For practical reasons, CALPUFF simulations of S2GF PM10 impacts were limited to a 1-year period.

PM10 predictions from both models were compared for two locations: downtown Abbotsford and the top of Sumas Mountain. Both models predicted maximum impacts on Sumas Mountain. CALPUFF does in fact predict higher concentrations than ISC although the differences are quite small. For example, the maximum PM10 24-hour average concentrations are 8.2 ug/m3 for CALPUFF and 7.4 ug/m3 for ISC. This finding suggests that the long-term statistics required for the CWS analysis can be based on the 5-year simulation generated by ISC.

4.4.2. Comparisons to the B.C. PM10 Objective

The B.C. PM10 ambient objective is 50 ug/m3 (24 hr average). On a calendar day basis, Abbotsford monitoring data from 1996 to 1998 indicate that exceedances of this objective occur on average from zero to four days per year.

The maximum predicted PM10 concentration in B.C due to S2GF emissions is predicted to occurs on Sumas Mountain. For worst-case oil firing conditions, the maximum 24-hour concentration is 8 ug/m3 (one day during the fall) and for the more common gas-firing condition, the maximum is 6.2 ug/m3 (one day during the fall).

The predicted PM10 impacts for areas surrounding Sumas Mountain are far lower. For example, the 24-hour PM10 impacts for downtown Abbotsford are predicted to be on the order of 1 ug/m3 under worst-case oil firing conditions and 0.5 ug/m3 under maximum gas-fired (duct firing) emission conditions. Given these low numbers, the impacts of the S2GF emission on the exceedance frequencies and magnitude of PM10 concentrations are expected to be minimal for the city of Abbotsford.

However, recent PM10 observations from Abbotsford show that a maximum value of 73 ug/m3 (rolling 24 hour average) was measured in July of 1996. If it is

assumed that these measurements apply to Sumas Mountain, this means that with S2GF emissions there is a potential for the maximum to now be 73 + 8 = 81 ug/m3 on Sumas Mountain.

The potential for this peak to occur was evaluated by the technical committee through a review the 1994 to 1998 hourly Abbotsford PM10 data in conjunction with the Abbotsford airport wind data. Wind directions for those hours with PM10 rolling 24 hour averages greater than 43 ug/m3 were reviewed. The choice of 43 ug/m3 was somewhat arbitrary, but it was thought that if the maximum predicted S2GF PM10 impact was in the order of 5 ug/m3, an exceedance of the B.C. objective of 50 ug/m3 may occur.

The analysis showed that during the summer and fall, the hourly winds were at times blowing from the southwest during the 24-hour period leading to elevated (greater than 43 ug/m3) 24-hour PM10 concentrations. This suggests that S2GF emissions could be carried to Sumas Mountain and contribute to exceedances of the objective for those occasions where the background PM10 level is sufficiently elevated. Thus it is possible that both the magnitude and exceedance frequency of PM10 on Sumas Mountain will increase over what is currently experienced. However, what is the likelihood of this situation actually happening?

One way to answer this involves the addition of PM10 measurements from Abbotsford (i.e. the observed background) to the predicted PM10 concentrations due to the S2GF emission for the simulation days (April 1998 through May 1999). A total PM10 concentration (observed background + predicted S2GF contribution) was produced for two locations, the Abbotsford urban area (where the PM10 measurements were taken) and Sumas Mountain (where the maximum PM10 impact is predicted to occur).

Based on the total concentrations, four exceedances (based on calendar days) were found for both locations (about 1.2% of the time over a year). In each case, the background accounted for 99% of the total predicted concentration. In other words, the contribution of PM10 due to S2GF under exceedance conditions is very minor. This suggests that S2GF emissions will not increase the frequency of exceedances already experienced in Abbotsford.

An alternate presentation of the data helps provide further insights. This involves adding the predicted maximum 24-hour impacts due to S2GF emissions, to the measured 24-hour average concentration for the same date and time of the predicted maximum impact. This information (Table 8) shows that the total PM10 concentrations (background+S2GF) on days with the highest impacts from S2GF are not expected to exceed of the B.C. PM10 objective. Table 8 also indicates that on these days the S2GF contributions to the total PM10 is mostly less than 20%. This analysis was based on calendar day PM10 averages. If rolling averages were applied, the modelled and observed PM10 values will increase. (the magnitude of the increase depends on a variety of factors). However given

the low total PM10 values relative to the objective, even if rolling averages were applied, it is still not likely that the S2GF emissions will result in an increase in exceedances at Abbotsford.

The PM10 analysis has focussed on one year. It is possible that if an analysis over 5 years was conducted with modelled and observed data, there may be some years where S2GF PM10 impacts are less than indicated here, and other years where they may be greater. However given that the total concentrations in Table 8 are low relative to the objective, the S2GF impacts and/or background levels would have to be far greater to create an increase in exceedances.

Table 8. Seasonal Maximum 24-Hour PM10 Predicted by CALPUFF.

Period	Day	Max. Predicted 24 Hr PM10 (µg/m3) due to S2GF (Sumas Mtn)	Simultaneous Obs. PM10 (µg/m3) @ Abbotsford (background)	Total PM10 (µg/m3) (S2GF+ Background)	Predicted S2GF Contribution to Total PM10 (%)
Spring 98	4/23/98	2.9	15	18	16
Summer 98	7/22/98	5.2	25	30	17
Fall 98	9/23/98	6.2	27	33	19
Winter 98/99	1/4/99	3.4	25	28	12
Oil Fired 98/99	1/4/99	8.2	25	33	25

4.4.3. Comparison to the New Canada-Wide Standard (CWS) for Particulate Matter

A CWS for PM2.5 of 30 ug/m3 (24-h average, annual 98th percentile, averaged over 3 years) was approved by the Canadian Council of Ministers of the Environment in early June.

The PM10 predictions produced by ISC for a five-year period were used by the technical committee to evaluate the potential impacts of S2GF on CWS attainment. Chilliwack is the only site in the LFV with sufficient data to calculate the PM2.5 CWS metric.

Since monitoring began in 1995, the PM2.5 CWS metric has not exceeded 18.2 ug/m3. Assuming PM10 emissions from Sumas2 are 100% PM2.5, and given a maximum predicted impact of 7.4 ug/m3, a conservative estimate of the resulting CWS metric is 26 ug/m3. Hence, it is unlikely that emissions from S2GF would result in the exceedance of the proposed PM2.5 CWS, providing background PM2.5 concentrations remain similar to historical levels.

4.4.4. Summary of PM Impacts

- The technical committee reviewed four years of wind and PM10 data and found that there is a potential for PM10 exceedance frequencies and magnitudes to increase on Sumas Mountain due to S2GF emissions. However, the chances of this occurring are small based on the following analysis:
  - The predicted incremental impacts and the observed PM10 levels over one year indicate that exceedances of the objective are almost solely attributed to high background concentrations as opposed to the emissions from S2GF.
  - When S2GF PM10 impacts are predicted to be the greatest, the observed background PM10 for the same day indicates that the total PM10 impact will not compromise the objective.
  - These above findings are based on an analysis of one year of modelled and observed PM10 data. Given that the total PM10 concentrations are low relative to the objective for this year, for other years the impacts of the S2GF emission and/or the background levels would have to increase dramatically to compromise the objective.

- Based on ISC-generated data, the technical committee does not expect that the recommended CWS for PM2.5 will be exceeded as a result of the emissions from S2GF.

4.5. Predicted Air Quality Impacts Due to S2GF Emissions - Visibility

4.5.1. Introduction

During the summer in the eastern reaches of the LFV, there are frequent occurrences of an intense white haze. Anecdotal reports (confirmed by photographs) indicate that the haze can completely obscure the bounding mountain ranges even during what apparently is a clear summer day.

Visibility (or the clearness with which an object stands out from its surroundings) is a result of a complex series of interactions between light and fine particles (primarily PM2.5) and gases in the atmosphere. In general, visibility deteriorates due to an increased amount of these visibility-reducing particles and gases.

Since S2GF will emit visibility-reducing pollutants, there is a concern that such emissions will result more frequent and intense haze events. The proponent has conducted studies on this matter, but due to the complex physical and human factors involved in visibility perception it must be appreciated that the assessment of S2GF visibility impacts is extremely difficult and the uncertainties large.

Studies show that visibility perception depends on variables such as sky conditions, the background vista, and human factors (internalized values, etc.). What may be acceptable to one person may not be acceptable to another. Furthermore, judgements may change depending on location, the vista and the viewing conditions.

Although a difficult issue to assess, MFG have conducted some quantitative estimates on visibility impacts due to the S2GF emissions under different emission scenarios, seasons and visibility conditions.

4.5.2. Visibility Parameters

Visibility is typically described in terms of one of three related parameters: visual range, light extinction and deciviews. Visual range and light extinction are used in this analysis.

Visual range refers to the distance at which the contrast of a visual target against a background is equal to the threshold contrast value for the eye; i.e. the target is just visible. It is commonly used in aviation forecasts, and is typically expressed in miles or km. It is a subjective measurement, based on an individual's judgement. It is affected by background colour, sun angle, time of day and season.

Light extinction is inversely proportional to visual range. It is a function of the absorption and scattering of light due to gases and particles in the atmosphere. It is typically expressed in units of inverse megametres Mm^{-1}. The greater the light extinction, the poorer the visibility and the lower the visual range.

4.5.3. Visibility Criteria (Standard)

There are no national or B.C. criteria for assessing visibility impacts. However, there are criteria that apply to U.S. national parks and wilderness areas (FLM, 1999). In additional, a local criteria was recommended based on visibility public perception studies in the LFV (Pryor, 1996). Both of these criteria were used in this assessment.

4.5.4.1. The U.S. Pristine Area Criteria

For evaluations of source impacts affecting national parks and wilderness areas in the U.S., a 5% change in daily averaged light extinction is used to indicate a "just perceptible" change in visibility. For these areas, *no days of perceptible changes in visibility are allowed*. Washington regulators used this criteria to evaluate the impact of S2GF on "Class I" areas in Olympic National Park and North Cascades National Park.

It may not be appropriate to use the U.S. criteria for this situation, as it is applied to visibility impacts on pristine areas where small changes in air quality can result

in large perceptible changes in visibility. Furthermore, such assessments for these areas typically involve sources at least 50 km from a view (i.e. farther than vistas in the Abbotsford area), or an aggregation of plumes from multiple sources (rather than the single S2GF source). Nevertheless, the U.S. criteria provides one benchmark in the S2GF visibility assessment.

4.5.4.2. A Recommended Local Criteria

Pryor (1996) recommended a local visibility criteria based on a public perception study to determine what level of visibility impairment the public deemed to be acceptable. The participants were shown a series of scenic vistas in Abbotsford and Chilliwack, and then rated the visual air quality of the scene. Based on the study results, Pryor recommended visibility criteria of approximately 60 and 40 km visual range for Abbotsford and Chilliwack, respectively. In otherwords, when visual range was less than these distances, visibility was unacceptable.

4.5.4. The Definition of Background (Baseline) Visibility

Establishing Background or baseline visibility conditions is critical in the assessment of the visibility changes due to S2GF emissions. If the baseline visibility is good (clear day when visual range is high), then the visual impact of the S2GF emissions will be detected readily. If the baseline visibility is poor (hazy day when visual range is low), then the S2GF emissions will not be noticed.

Since visibility is determined in large part by the amount and nature of PM, the determination of typical good, moderate and poor baseline visibility is associated with low (clean conditions), moderate and high (dirty conditions) PM concentrations. These types of measures were taken during two local studies - REVEAL (summer 1993) and REVEAL2 (spring 1994 – spring 1995). As well, measurements of visibility-related particles were made near Abbotsford (1996 – 1997) by Environment Canada.

The Environment Canada data PM data was used to extract 10^{th}, 50^{th} and 90^{th} percentile which corresponds to typical low, moderate, high PM concentrations for each season. The baseline visibility associated with these three PM concentration levels was constructed for six lines of sight (LOS) to commonly viewed vistas in the region (Figure 2). The seasonal baseline visibility conditions were adjusted for each LOS according to CALPUFF predicted humidity conditions along each LOS.

This is similar to the approach used to assess visibility impacts for U.S. national parks and wilderness areas, where good and poor baseline visibility is based on the seasonal averages of the 20% lowest PM concentrations days and the 20% highest PM concentration days. It was assumed that these two parameters are equivalent to the 10^{th} and 90^{th} percentile PM concentrations used in this baseline analysis.

Figure 2. Lines of Sight Evaluated for Visibility Assessment

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Note that "clean" and "poor" conditions are relative terms. For example because PM concentrations are generally lower in winter than in the summer, the 10th percentile particulate concentration for the winter is lower than the summer value. Thus the visibility during typical *winter* clean conditions will be better than the visibility during typical *summer* clean conditions.

4.5.4.1. Current Baseline Visibility Conditions

Seasonal baseline visibility (i.e. no S2GF emissions) was evaluated relative to the local recommended visual range criteria of 60 km. Unacceptable or impaired visibility occurred whenever the light extinction associated with the baseline condition exceeded the light extinction associated with the criteria of 60 km.

The analysis indicates that the best baseline visibility occurs during the winter and fall where these seasons experience the lowest chance of impaired visibility. However, even during clean days, depending on the LOS considered, for the fall there is up to a 40% chance of impaired visibility. For the winter, for clean days there is a 15 - 25% chance that the visibility during a clean day will be impaired (unacceptable). This indicates that even under so-called clean (low particulate concentration) conditions, there is a good chance that the visibility impairment can still occur.

For the summertime, the PM concentrations are consistently high enough so that even under "clean" conditions, visibility there is 100% chance of visibility impairment. In other words, when 24 hour periods are considered, the analysis suggests that visibility is unacceptable *all the time* during the summer. Although this seems suprising, it supports anecdotal reports of consistent unacceptable summertime visibility in this part of the LFV.

4.5.5. Predicted S2GF Visibility Impacts

CALPUFF calculated the light extinction values for each LOS due to the S2GF emissions under maximum gas-fired and oil fired emissions. A combination of baseline visibility conditions for different seasons and different emission scenarios and the light extinction due to S2GF emissions for each LOS was evaluated. The impacts were judged relative to the U.S. pristine areas criteria and the local recommended criteria.

Under the common gas-firing scenario, with few exceptions the greatest visibility impacts due to S2GF emissions were predicted to occur along LOS1 (Abbotsford to Sumas Mountain). Under clean baseline conditions, the greatest visibility impacts occur during the fall, when background PM concentrations are generally low and light extinction due to S2GF emissions are relatively high. Under clean baseline conditions during the fall, predictions show that S2GF emissions will result in exceedances of the U.S. pristine areas visibility criteria along LOS1–

LOS5. Furthermore, the number of days where there would be a perceptible difference in the visual range due to S2GF emissions ranges from 0 to 8 days. This range represents upper and lower bounds to these estimates. The 8 days assumes that every day during the spring is clean (a very unlikely event). The 0 days assumes that every day during the fall is poor (again, a very unlikely event). For the winter, the range is 0 to 2 days.

With respect to the recommended local visibility criteria, for clean baseline conditions during the fall, there will be an increase of 0 to 5 days where the recommended local criteria is exceeded due to S2GF emissions. The range reflects the upper and lower bounds of the predictions. For summer, there will be no increase in the number of days of impaired visibility due to S2GF emissions (an expected result since the baseline visibility is impaired 100% of the time). In otherwords, since current visibility is consistently unacceptable during the summer, the addition of any more emissions (including those due to S2GF) cannot increase the frequency of these periods.

The greatest overall impacts are expected to occur during the winter under oil-firing. Assuming oil firing occurs for every day during the winter, for clean conditions, the U.S. pristine area criteria is exceeded along 5 of 6 lines of sight. There is predicted to be from 0 to 23 days where there will be a perceptible reduction in visual range due to S2GF oil fired emissions. The 23 days estimate is unrealistic, since oil firing is only anticipated to occur for a maximum of 15 days during the winter. However, the analysis does indicate that for some lines of sight (LOS1,3,5) it is possible that there will be a perceptible reduction in visual range for every oil firing day. The number of days in which the recommended local standard is exceeded increases by 0 to 7 days. Again the upper bound is conservative as it assumes that oil firing occurs every day during the winter and clean conditions exist for every day (an unlikely event).

Oil-fired operations only occur during rare gas shortages during the winter, when temperatures are low and demand for natural gas is high. Based on MFG's analysis, winds tend to be from the north when temperatures are low. This suggests that S2GF emissions under oil-firing will blow into the U.S. rather than B.C. An analysis of Abbotsford Airport wind data collected during the REVEALII study (1994-1995) confirms that during the 15 coldest days in the winter, the prevailing wind direction was from the NNE-NE. Hence, actual impacts during oil-fired operations in B.C. may be significantly less than predicted.

4.5.6. Visible Plume Perception

There is a concern that the gas turbine plume can be a visual detriment. This is different than the previous visibility assessment, where the contribution of S2GF to regional visibility was analyzed. Based on a review of plant operators of these types of facilities, there was unanimous agreement that there is no visible plume (except from condensed water vapour with high humidity) from those plants with

NOx emissions less than 10 ppm (S2GF meets this criteria). One operator familiar with gas and oil-fired plants asserted that the plume was not visible with either fuel.

4.5.7. Summary

- Abbotsford already experiences frequent periods of poor visibility, especially during the summer.

- S2GF emissions will impact visibility in the Abbotsford area. The magnitude of these impacts depends on the time of year, the line of sight and the background visibility conditions.

- Irrespective of season or operating conditions, the greatest visibility impacts due to S2GF emissions are predicted to occur along Line of Sight 1 (Abbotsford to Sumas Mountain). There are no visibility impacts along Line of Sight 6 (Chilliwack to Mt. Sleese) at any time.

- When S2GF is gas-fired, the greatest impacts occur during the fall. Under clean background conditions, visibility impacts will exceed the U.S. criteria and cause an increase of 0 to 5 days (upper and lower bound estimates) in which the recommended local criteria is exceeded along some lines of sight. During worst-case background conditions the visibility impacts are zero or very small.

- The highest potential impacts will occur during the winter when S2GF is oil-fired. Under clean background conditions, it was found that S2GF emissions under oil-firing will cause frequent exceedances of both the U.S. pristine areas criteria and the recommended local criteria. However, these estimates are considered to be conservative, as they assume oil-firing for every winter day. As well there are indications that during rare gas-shortage events, wind data suggests that B.C. will be located upwind of S2GF (i.e. visibility impacts confined to areas south of the border).

- Based on a survey of other operators of similar power generation facilities, there should be no visible plume (other than water vapour under high humidity conditions) when gas-fired, and little likelihood of a visible plume even under the uncommon, oil-fired conditions.

4.6. Cooling Tower Plume Impacts

The cooling towers emit water vapour that can have a variety of impacts, depending on the meteorology and facility operation. These impacts are: (1) visible impacts due to condensed plumes, (2) fogging and/or icing involving the ground contact of visible plumes, (3) shadowing effects (where the condensed plume casts a shadow), and (4) the impact of sustained deposition of droplets of

cooling water, called drift. A cooling tower plume computer model was used with 5 years of meteorology as input. The modelling showed:

- Visible plumes would be of short duration and will not obscure visual resources in the area. During periods when condensed plumes would be noticed (i.e. daytime, good background visibility), a condensed plume would be less than 50 m in length on average. Under such conditions, there is a 1% chance that a condensed plume longer than 1 km will occur.

- Except for an area within 100 meters of the cooling tower, plume shadows would be limited to less than 120 hours per year.

- Plume induced ground-level fog would occur less than one hour per year.

- Icing was not predicted to occur

- The deposition of water droplets and the minerals in the water (drift) will be low and confined to an area within 100 m of the cooling tower. No build-up of drift in the surrounding area is anticipated.

4.6.1. Greenhouse Gas Emissions

Greenhouse gases emissions are relevant only to the issue of global climate change. Although they have no direct local or regional air quality impact, they are raised here due to the importance of this issue.

S2GF is anticipated to emit 2.2 million T/y of CO2. Burrard Thermal, if operated at maximum power generation capacity (7000 GW h), can potentially emit 3.7 million T/y of CO2. However as discussed earlier, it has only reached 60% of its maximum generation capacity. In 1995, Burrard Thermal emitted about 2.2 million Tonnes of CO2.

The issue of the management of greenhouse gas emissions due to this project is subject to U.S. regulations. These are largely driven by international agreements which also provide the impetus for the Canadian and B.C. greenhouse gas management programs.

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